JDEM Detector Status Summary

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September 26, 2009

JDEM Detector Activities Update

- **The JDEM Project is studying mission configurations that have only HgCdTe detectors and no CCDs. These configurations could potentially use the near-IR imaging camera for a unique measurement of Weak Lensing galaxy shapes.**

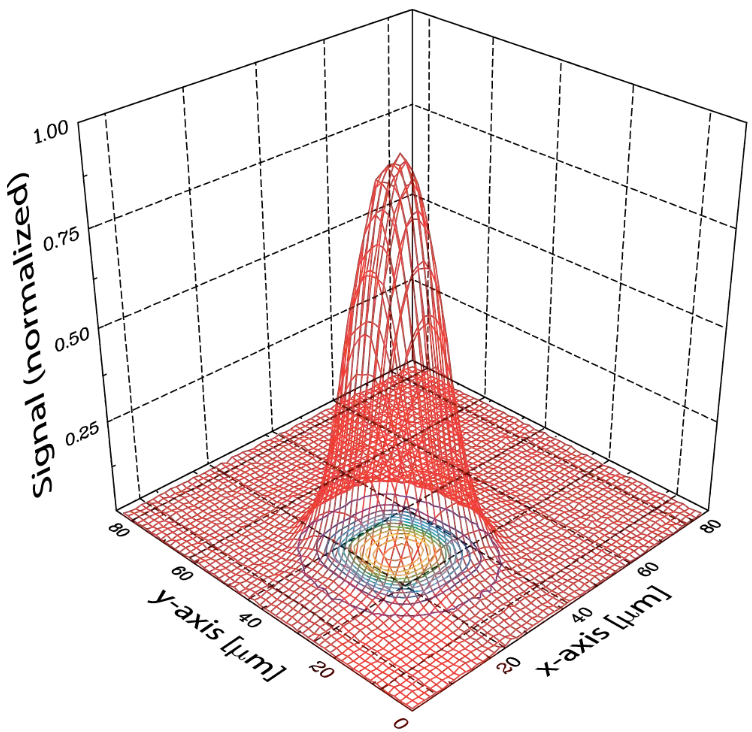
- **There are some residual questions about the suitability of the near-IR HgCdTe detectors since there are known features that may contribute to shape noise or systematic errors.**

- **As promised at the presentation in Pasadena, the Project is hereby giving a status update on a program to assess the suitability of HgCdTe detectors for Weak Lensing measurements.**
    - Also assessing areas of improvement in HgCdTe detector performance that may improve their ability to support Weak Lensing measurements.

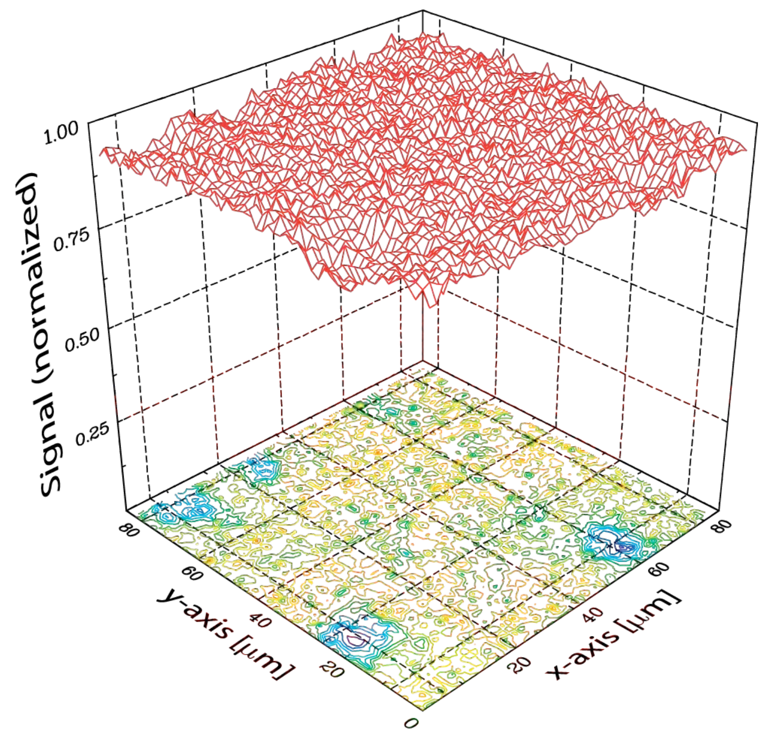
HgCdTe For Weak Lensing

- **Intra-pixel response of HgCdTe detectors has been extensively studied.**
  - Next slide shows intra-pixel response. First order behavior is outstanding.
- **The following effects are known idiosyncrasies of HgCdTe detectors.**
  - Inter-pixel capacitance: capacitively couples the signal seen at a pixel to its four nearest-neighbor pixels.
  - Reciprocity: a bright source for a short integration time does not give the same signal as a dim source for a correspondingly longer integration time.
  - Persistence: retains a “ghost” of a previous integration in the current integration.
- **These effects are modeled into simulated WL galaxy field, and the galaxy ellipticities are then recovered.**
  - Initially, this is without correction, with the goal of providing the best corrections possible as they are needed and developed.
  - Systematic error budget in ellipticity magnitude is roughly 0.001.
- **To ensure that all effects are accounted for, an end-to-end optical test with a real detector is being planned to verify ability to recover ellipticities with the required accuracy.**

HgCdTe Intra-pixel Response is Well Behaved For Point and Uniform Illumination



Single-pixel response to a two-dimensional scan over a 4x4 array of pixels at a wavelength of 1050 nm. The grid on the bottom represents the physical size of the pixels.



Response map to a two-dimensional scan over an 8x8 array of Pixels at a wavelength of 1050 nm. Only the response of the Inner 4x4 array is shown.

Subpixel Response Measurement of Near-Infrared Detectors," N. Barron et al, PASP 119, pp 466–475 (2007).

Results Summary

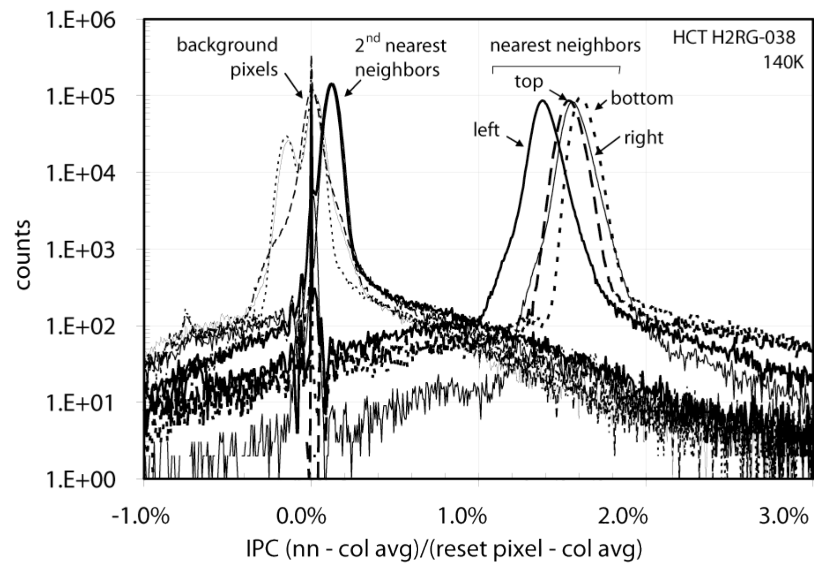
- **These results are preliminary as we are currently about one quarter complete on the intended activities.**
- **None of the three idiosyncrasies considered are believed to be show stoppers.**
  - IPC: characterized to first order and will likely be acceptable. Detector improvements are very possible and some are already implemented in the post-JWST generation.
  - Reciprocity: magnitude shown by HST WFC3 to be relatively small and quantifiable. All flight detectors could be measured as a part of normal ground calibration.
  - Persistence: magnitude is known and likely acceptable by appropriate field dithering. Detector improvements are demonstrated with a factor of ~ 10 improvement over the already low levels in JWST detectors.
- **The detailed simulation phase is starting and will quantitatively integrate all these effects to assess their impact on the ellipticity measurement.**

Inter-Pixel Capacitance

- **The effect arises from stray capacitance in the detector, multiplexer, and connecting Indium bumps.**
  - The magnitude of this capacitance relative to the integration node capacitance controls the magnitude of the effect.
    - If the integration node capacitance is made larger, the effect decreases, but the voltage gain of the detector is also reduced, leading to higher effective noise.
  - Coupling to each nearest neighbor pixel is roughly at the 1% level for JWST-era detectors.
- **The effect of this JWST-level of IPC has been calculated for the ellipticity measurement.**
  - Initial modeling shows that, without correction, this is roughly the entire systematic error budget.
  - Correction algorithms are expected to be able to achieve the 10% accuracy levels that will bring this effect to acceptable levels.

Inter-Pixel Capacitance

- **Measurements on representative devices have been made to characterize the pixel-by-pixel variation of this effect.**
  - There is roughly 10% variation of the IPC magnitude across a detector. Figure to right is from: “Mapping electrical crosstalk in pixelated sensor arrays,” S. Seshadri, D. M. Cole, B. R. Hancock, and R. M. Smith, Proc. SPIE 7021, 702104 (2008).
  - Correction of ellipticities using only the mean IPC should be sufficient, but we can likely do better.



- **Can be reduced by changes to the detector, multiplexer, and/or Indium bump geometry/backfill epoxy dielectric constant.**
  - Roughly a factor of 2 improvement over JWST is already achieved for the new generation of multiplexers.
  - Another factor of ~ 2 has been demonstrated at the detector level with changes in pixel structure.
  - Additional process improvements are being investigated to either remove the backfill epoxy, or reduce its dielectric constant. The epoxy backfill study was published: “Correlated Noise and Gain in Unfilled and Epoxy-Underfilled Hybridized HgCdTe Detectors,” M. Brown, M. Schubnell, and G. Tarlé, PASP 118, pp 1443–1447 (2006).
- **Current conclusion: characterized to first order and will likely be acceptable. Detector improvements are very possible and some are already implemented in the post-JWST generation.**

Reciprocity

- **Affects several important measurement aspects.**
  - Galaxy shapes see this as a suppression of the core relative to the extended regions.
  - Field star PSF measurements (needed to correct for galaxy PSF) will also see the core suppressed relative to the wings.
  - Transfer of flux calibration from bright objects to the galaxy fluxes will be directly affected by the reciprocity magnitude.
- **Shapes will be directly affected much less because the dynamic range within a galaxy is small compared to the field star/galaxy flux ratio.**
- **The magnitude of the effect is roughly 1% effective QE depression for each factor of 10 in flux.**
  - This is correctable with an appropriate ground calibration effort.
  - Varies by roughly a factor or 2 or 3 among different devices, but very few devices have been accurately characterized for reciprocity.
- **The physical cause is not understood but HST/WFC3 is actively investigating.**
  - Some more work is needed to understand stability with time.
- **We currently have a baseline form and magnitude for this effect defined and are starting the simulations to determine its overall effect on ellipticity.**
- **Current conclusion: magnitude shown by HST WFC3 to be relatively small and quantifiable. All flight detectors could be measured as a part of normal ground calibration.**

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Persistence

- **The magnitude of this effect is roughly 0.1% in the next exposure.**
- **Extensive data available from other programs for this effect.**
  - JDEM has reviewed the data to establish a starting value to use for analysis:

    "Calibration of image persistence in HgCdTe photodiodes," Roger M. Smith, Maximilian Zavodny, Gustavo Rahmer, and Marco Bonati, Proc. SPIE 7021 (2008).

    "A theory for image persistence in HgCdTe photodiodes," Roger M. Smith, Maximilian Zavodny, Gustavo Rahmer, and Marco Bonati, Proc. SPIE 7021 (2008).

    "Image persistence in 1.7 μm cut-off HgCdTe focal plane arrays," R. Smith et al, IEEE NSS '07, Volume 3, pp 2236 – 2245 (2007).
- **The form and magnitude has been prepared for the simulations.**
- **The physical cause of this effect is determined in the JWST-style detectors.**
  - A factor of 10 reduction has been shown using a slightly modified structure intended to minimize the cause.
- **JDEM is also tailoring the sky scanning strategy to minimize the systematic effects of persistence.**
  - For instance, dithering by multiple pixels can reduce a systematic component to a potentially random component.
- **Current conclusion: magnitude is known and likely acceptable by appropriate field dithering. Detector improvements are demonstrated with a factor of ~ 10 improvement over the already low levels in JWST detectors.**

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Verification Strategy

- **The current activities all attempt to model known detector effects to determine their scientific impact.**
  - If an effect is not identified and properly quantified, then it is possible that it could cause unexpected problems late in the game.
- **Another way to approach the problem is to emulate the observations optically and measure the response of a real detector to these emulated images.**
  - For example, project onto the detector a galaxy field where the ellipticities are known.
  - We can then apply the corrections developed through the simulations, to ensure that the ellipticities are properly recovered.
  - If some effect is mis-estimated or not accounted for, there will be unexplained errors in these results.
- **Working with Roger Smith/Caltech and Suresh Seshadri/JPL to start this planning for JDEM.**
  - Testing with JDEM detectors could start as early as mid- to late-2010.
  - See following figure of test apparatus
- **This is a crucial test for the very demanding WL measurements.**
  - Ideally, performance will be confirmed in this end-to-end manner to determine optimal pixel field-of-view.

HgCdTe Weak Lensing Test Apparatus

Test apparatus currently in assembly on existing optical bench